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PENNYWORT AND DUCKWEED MARSH SYSTEM FOR UPGRADING WASTEWATER EFFLUENT FROM A MECHANICAL PACKAGE PLANT

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ABSTRACT

A small artificial marsh system has been used to upgrade the effluent from a mechanical package plant for over seven years. The artificial marsh has a hydraulic retention time of 7 to 8 d. Although originally stocked with water hyacinth (*Eichhornia crassipes*), extremely cold winters shifted the predominant aquatic macrophyte from the water hyacinth to a dual system of pennywort (*Hydrocotyle umbellata*) in the summer and duckweed (*Lemna*, *Spirodela*, and *Wolffia* spp.) in the winter.

The artificial marsh system maintained the wastewater in aerobic conditions. The yearly average effluent BOD_5 was reduced from 35.5 mg L^{-1} to 6.2 and 3.0 mg L^{-1} with water hyacinth and pennywort/duckweed, respectively. The yearly average TSS were reduced from 47.7 mg L^{-1} to 5.8 and 11.5 mg L^{-1}, respectively. The artificial marsh system proved to be an effective and reliable post-treatment process to upgrade the effluent from a mechanical package treatment plant to secondary standards of 30 mg L^{-1} BOD_5 and TSS.

Keywords: Duckweed, water pennywort, *Lemna*, *Spirodela*, *Wolffia*, *Hydrocotyle umbellata*, artificial marsh, wastewater treatment.

INTRODUCTION

Floating vascular aquatic plants, particularly the water hyacinth (*Eichhornia crassipes*), have proved useful as an integral part of major domestic wastewater treatment systems (Dinges, 1978; McDonald and Wolverton, 1980; Wolverton and McDonald, 1979a,b). Other floating plants such as duckweed (*Lemna minor*, *Spirodela polyrhiza* and *Wolffia* sp.) and pennywort (*Hydrocotyle umbellata*) can be used in biological treatment systems to bridge the gap during the winter months when water hyacinth growth is reduced or stopped (Boyd, 1969; Culley and Epps, 1973; Reddy and DeBusk, 1984,1985a,b).

The National Aeronautics and Space Administration (NASA) at the National Space Technology Laboratories (NSTL) has several vascular aquatic plant waste treatment systems. One is used to upgrade a mechanical package treatment plant which treats domestic sewage from 64-68 office workers. Comparative data from this system are presented here.

SYSTEM DESCRIPTION

The mechanical package plant at NSTL, Mississippi, is a small system, 2.1 m (7 ft) in diameter which treats approximately 7.57 m^3 of domestic sewage daily. Originally installed in 1965, no additional office space was tied into the system and total personnel fluctuated little during the study period 1977-1985. During the winter of 1978-79, effluent from the package plant was diverted into an artificial marsh system consisting of a reservoir 35 m L x 4.3 m W x 0.38 m D, lined with 20 mil PVC. Effluent from the package plant enters one end of the pond and is discharged through a tablet chlorinator at the other end. The flow rate is estimated to be 7.57 $m^3\ d^{-1}$ and has not significantly changed over the years.

The new reservoir was originally stocked with water hyacinths in February, 1979, with coverage reaching 100% during the first summer. After the first three years, extremely cold winters in the area caused the dominant aquatic vegetation to shift from water hyacinth to pennywort in the spring and summer and duckweed in late fall and winter. In the winter (December through March), pennywort covered 90% of the lagoon surface with duckweed filling in around the plants. By May of each year, pennywort coverage would naturally reduce to less than 20% of the lagoon surface and a thick duckweed cover over the entire surface would form. Water hyacinths were partially harvested once each summer during 1979 and 1980. After that no further plants have been removed from the system.

MONITORING AND ANALYSIS PROCEDURES

Grab samples were collected biweekly at the discharge point of the package plant prior to installing the reservoir for aquatic plants. After the artificial marsh system was included in the treatment train, a representative sample from the discharge of the package plant was no longer possible since the intake to the reservoir was submerged. At that time grab samples were taken biweekly at the discharge point of the artificial marsh.

Dissolved oxygen (DO) measurements were taken in the field using a portable YSI O_2 meter and probe. The samples were analyzed for 5 d biochemical oxygen demand (BOD_5), total suspended solids (TSS), and pH according to standard methods (APHA, 1971).

RESULTS AND DISCUSSION

There was little pH variation in the package plant effluent when treated with water hyacinth or pennywort/duckweed. All pH values were in the acceptable range of 6.0-9.0. Average pH values were 7.34 ± 0.37, 7.57 ± 0.31 and 7.24 ± 0.16, for package plant effluent and effluent treated with water hyacinth and pennywort/duckweed, respectively.

The DO measurements (Table 1) indicate that water hyacinth is more effective in reoxygenating the water than pennywort/duckweed. The yearly average effluent DO of 4.4 mg L^{-1} with water hyacinth was almost double the average DO with pennywort/duckweed. The most significant differential occurred during the winter months of December through March. Every DO measurement taken year-round was above 1.0 mg L^{-1}, indicating that the system remained aerobic throughout the year.

In general, the extent of the root system of water hyacinth was greater or equal to that of pennywort. Emergent hydrophytes *Menyanthes trifoliata* and *Eriophorum angustifolium*, *Oryza sativa*, and *Spartina alterniflora* reported to release O_2 from their root tips into an anaerobic environment. Oxygen was possibly emitted into the aqueous medium from the roots. Sculthorpe and Duncan (1967) reviewed this subject and concluded that linear gradients of O_2 concentration in shoots to roots support the hypothesis that underground organs derive their O_2 supply from the aerial or floating foliage. In addition, mature foliage which has ceased to

TABLE 1. Average dissolved oxygen (DO) for package plant effluent before and after the addition of an aquatic plant treatment system.

Month	Package plant effluent (1977-78)	Effluent Treatment: Water hyacinth (1979-80)	Effluent Treatment: Pennywort and Duckweed (1984-85)
	DO, mg L^{-1}		
June	3.1	2.3	1.5
July	3.7	3.8	3.1
August	3.3	4.1	1.9
September	3.7	2.3	1.6
October	4.5	1.9	1.7
November	4.1	3.4	2.4
December	2.6	7.4	2.8
January	4.7	7.0	2.6
February	4.7	7.2	3.0
March	3.8	6.0	3.0
April	3.5	3.7	1.9
May	2.7	3.9	1.8
Yearly Average	3.7	4.4	2.3

TABLE 2. Average 5 d biochemical oxygen demand (BOD_5) for package plant effluent before and after the addition of an aquatic plant treatment system.

Month	Package plant effluent (1977-78)	Effluent Treatment	
		Water hyacinth (1979-80)	Pennywort and Duckweed (1984-85)
	BOD_5, mg L^{-1}		
June	22.6	7.5	2.8
July	15.6	3.4	0.2
August	27.3	5.2	1.8
September	115.1	2.3	2.8
October	27.7	5.1	3.0
November	19.9	7.9	3.6
December	41.7	7.3	2.0
January	50.9	5.7	2.7
February	61.5	6.3	1.5
March	15.5	11.9	2.0
April	14.5	7.0	6.4
May	13.8	5.3	7.0
Yearly Average	35.5	6.2	3.0

TABLE 3. Average total suspended solids (TSS) for package plant effluent before and after the addition of an aquatic plant system.

Month	Package plant effluent (1977-78)	Effluent Treatment	
		Water hyacinth (1979-80)	Pennywort and Duckweed (1984-85)
	TSS, mg L^{-1}		
June	39.8	8.3	16.9
July	38.0	6.5	6.7
August	58.9	3.6	1.5
September	38.6	6.8	4.0
October	46.3	3.6	8.5
November	51.1	2.9	8.0
December	52.0	9.5	10.7
January	56.5	1.5	13.0
February	67.3	6.4	12.8
March	39.8	6.5	25.7
April	56.0	7.1	15.6
May	28.4	6.7	15.5
Yearly Average	47.7	5.8	11.5

grow supplied more O_2 to underground or submerged organs than young leaves do.

The BOD_5 reductions (Table 2) clearly indicate the benefit of having post-treatment with an artificial marsh system. The mechanical package plant alone provided secondary treatment approximately 66% of the time. After a 7 to 8 d detention in the artificial marsh system, the effluent BOD_5 averaged 6.2 mg L^{-1} with water hyacinth and 3.0 mg L^{-1} with pennywort/duckweed.

The mechanical package plant effluent contained over 30 mg L^{-1} total suspended solids (TSS) on a monthly average basis all but one month of the 12 month data period (Table 3). The artificial marsh system consistently brought the TSS concentrations below 30 mg L^{-1} as shown in Table 3. The TSS trend with water hyacinth and pennywort/duckweed was opposite to that for BOD_5. The pennywort/duckweed yearly average TSS of 11.5 mg L^{-1} was almost double the yearly average of 5.8 mg L^{-1} for water hyacinth.

The artificial marsh system in this application proved to be an effective and reliable system to upgrade effluent from a mechanical package plant. The system construction was simple and the yearly maintenance since its installation in early 1979 minimal. The system has operated since 1980 with no harvesting or external energy inputs. Mosquito breeding is not a problem due to a large population of mosquito fish (Gambusia sp.) which can survive due to the aerobic conditions.

REFERENCES

American Public Health Association (APHA). 1971. Standard methods for the examination of water and wastewater. 13th ed. APHA, Washington, DC.

Boyd, C. E. 1969. Vascular aquatic plants for mineral nutrient removal from polluted waters. Econ. Botany 23:95-103.

Culley, D. D., and E. A. Epps. 1973. Use of duckweed for waste treatment and animal feed. J. Water Pollut. Control Fed. 45:337-347.

Dinges, R. 1978. Upgrading stabilization pond effluent by water hyacinth culture. J. Water Pollut. Control Fed. 50:833-845.

McDonald, R. C., and B. C. Wolverton. 1980. Comparative study of wastewater lagoon with and without water hyacinth. Econ. Botany 34:101-110.

Reddy, K. R., and W. F. DeBusk. 1984. Growth characteristics of aquatic macrophytes cultured in nutrient-enriched water: I. Water hyacinth, water lettuce, and pennywort. Econ. Botany 38:229-239.

Reddy, K. R., and W. F. DeBusk. 1985a. Growth characteristics of aquatic macrophytes cultured in nutrient-enriched water. II. Azolla, duckweed, and salvinia. Econ. Botany 39:200-208.

Reddy, K. R., and W. F. DeBusk. 1985b. Nutrient removal potential of selected aquatic macrophytes. J. Environ. Qual.

Wolverton, B. C, and R. C. McDonald. 1979b. Water hyacinths for upgrading sewage lagoons to meet advanced wastewater treatment standards. NASA Technical Memorandum TM-X-72720, October 1979.

Sculthorpe, C. D. 1967. The biology of aquatic vascular plants. Edward Arnold Ltd., London. p. 157-164.

Wolverton, B. C., and R. C. McDonald. 1979a. Upgrading facultative wastewater lagoons with vascular aquatic plants. J. Water Pollut. Control Fed. 51:305-313.